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AFTER THE 'AFFLUENT SOCIETY': COST OF LIVING IN THE PAPUA NEW GUINEA HIGHLANDS ACCORDING TO TIME AND ENERGY EXPENDITURE–INCOME

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Summary. What is the cost of living in the Papua New Guinea highlands? An answer is sought using a time and energy accounting approach. The subsistence regime of Wola-speaking highlanders, the subjects of this investigation, comprises three components. The principal one is horticulture: people clearing gardens from forest and grassland, with tuberous crops predominating, notably sweet potato. The second component comprises animal rearing, notably of domestic pigs. The third, and least important, is hunting and gathering for food in the forest. The calculated returns on investments in these subsistence domains vary considerably. Gardens return in their crops between ten and fifteen times the energy expended in cultivation. Pigs may also give a good return, of four to five times the energy invested in rearing them, if slaughtered when adult, but people regularly keep animals for years and may incur negative energy returns on their labour investments. This relates to the high cultural premium put on pigs. Foraging for food is also energetically costly, the Wola expending four times more energy on these activities than they gain in return from the food they secure. This analysis of energy gains and losses challenges the relative notion of affluence as applied to foragers, by reviewing it in the comparative context of subsistence horticulture.

Introduction

A review of data on hunter–gatherer subsistence activities discussed in the 1960s at a conference entitled 'Man the Hunter' prompted apparently outrageous claims of affluence. An on-going debate has ensued into the costs and benefits of hunter–gatherer life (Lee & Devore, 1968; Sahlins, 1972; Altman, 1984; Bird-David, 1992; Kaplan, 2000; Rowley-Conwy, 2001). The argument is that the hunter–gatherer way of life is not the hard travail once thought. According to Lee (1968) the !Kung Bushmen can supply their subsistence needs working one day in every four or five. An Arnhem Land Aborigine (Altman, 1984) spends 2·9 h a day hunting with an average return of 4773 kcal, suggesting that today (using firearms) he can supply his daily energy requirements in about 1·5 h. Data from a range of foraging societies (South American, African, South-east Asian and Australian; Kelly 1995; Tables 3–7) support these statistics with overall average daily hunting returns being enough to supply a hunter for 9 days. The affluence argument implies a reversal of Victorian-derived evolutionary assumptions, suggesting that life becomes less affluent as we move from hunting and gathering to a farming existence. This paper supplies comparative data with which to assess this proposition. It aims to assess the costs of living under a predominantly farming subsistence regime in the highlands of Papua New Guinea, where people engage infrequently in hunting and gathering.

The Wola of highland New Guinea traditionally subsist by cultivating gardens, keeping pigs and occasionally hunting and gathering wild resources, and the majority of the population continue to do so. Data on these subsistence activities, documenting inputs and outputs, have been collected over several years. They invite an investigation of rate of return for effort. One currency for assessing the cost of living under such a subsistence regime is energy. The energetics approach comprises a significant strand in the study of human ecology as it has developed since the 1960s (Lee, 1969; Moran, 1982; Ellen, 1982, 1996; Dwyer, 1983). It is conceptually straightforward, drawing on the ecosystem concept and seeking to equate energy expended with energy earned (as in the equation: energy balance = energy in – energy out) but methodologically difficult.

Another question related to the affluence hypothesis concerns the extent to which different subsistence strategies change the balance of work and rewards between women and men. Some writers prefer to reverse the customary hunter–gatherer label to gatherer–hunter to underline the importance of women's plant and small game foraging contribution to this livelihood regime (Meehan, 1974). Others question the assumption that women are responsible for a disproportionate share of the work. The Arnhem Land data (Altman, 1984) demonstrate that today men contribute overwhelmingly more bush food to the diet than women and they suggest that previously both may have contributed equally. In addition, data from several foraging societies (Kelly, 1995, p. 21) indicate that men engage 4·3 h a day to women's 3·3 h in food-getting activities (such a generalization is of academic interest only given the wide variety of subsistence regimes characterizing foraging societies). The highlanders of New Guinea are well known for their discrimination of men's activities from women's, distinctions underscored by men's fears of women's abilities to harm them (Strathern, 1972; Sillitoe, 1979a; Josephides, 1985; Lederman, 1986). The data analysed here quantify differences between women's and men's contributions to subsistence activities. The difference is considerable, although interpreting its significance is subject to dispute. Indeed, interpreting the entire subsistence regime is problematic, as in energetic terms it seems in some respects wasteful, if not profligate. Whether this is evidence of affluence is debatable but it does underline the importance of seeing subsistence activities in wider cultural context and not merely biologically in adaptive terms.

The Wola

The Wola speakers occupy five valleys in the Southern Highlands of Papua New Guinea, between 6 ° 0′/15′ latitude south and 143 ° 15′/45′ longitude east. They live at

1600–2000 m above sea level, between the Ak river in the west and the Mendi in the east. The data discussed here come from the Nipa Basin Census Division, notably the Was valley in the west. A recently folded mountainous region, it supports lower montane rainforest (CSIRO, 1965). People live along the valley sides, leaving the intervening forested watersheds largely unoccupied. In the valleys, where they have cultivated extensively, there are areas of dense cane grassland. Cash crops are few. The region's climate is of the 'Lower Montane Humid' type (according to McAlpine *et al.*'s scheme (1983), p. 160), characterized by high rainfall and cool temperatures.

A prominent feature of Wola social life is the exchange of wealth between defined categories of kin on specified social occasions, such as at a marriage or following a death, sometimes bringing together large numbers of people (Sillitoe, 1979b). These transactions remain today a significant force for order in their fiercely egalitarian acephalous society with weak central government authority. Lawless 'rascal' activity is prevalent throughout the region. Men who excel at exchange achieve locally positions of renown and influence, earning the appellative *ol howma*, approximating to 'bigmen' elsewhere. But 'bigmanship' does not extend to authority to direct the actions of others. People live in homesteads comprising nuclear or extended families, indistinctly grouped together on territories, resulting in loosely constituted patrifilially biased bilateral kin corporations. Wolaland is divided up into a large number of territories to which these kin-composed groups, called *sem* 'families', claim rights collectively, structuring access to land (Sillitoe, 1999a). Supernatural beliefs are centred on ancestors' spirits causing sickness and death by 'eating' vital organs, others' powers of sorcery and 'poison', and malevolent forest spirits. Today many people profess to be Christians and attend mission services.

The region is described as peripheral in development terms, although the Highlands Highway runs through Wola territory. But with gas and oil finds the position may change, with exploitation of these in the near future. The government station at Nipa in the Nembi valley has some administrative offices, including nominally a police station, a high school and health centre, and several trade stores. While the population continues to depend on local food production to meet most of its needs, it has some access to imported processed foodstuffs, which can have a significant impact on nutritional status, as demonstrated for the neighbouring Huli who have access to Tari town (Umezaki, Yamauchi & Ohtsuka, 1999; Kuchikura, 1999).

The livelihood regime

Horticulture

The Wola are skilful horticulturalists. Sweet potato is the staple, typically cultivated in composted mounds. Other crops include bananas, taro, various cucurbits and greens. The farming regime spans a range of management practices from classic shifting cultivation (sites cultivated once before abandonment to natural fallow for many years) through to semi-permanent farming (fertility managed through composting and the occasional brief fallow under grass) (Bourke *et al.*, 1995, p. 61; Sillitoe, 1996). About one-third of land currently under gardens is cultivated for the first time and the remainder are recultivations. These agricultural practices result in two broad classes of garden: those cleared and planted once with a wide variety of crops, and those cultivated repeatedly, sometimes over decades, with brief fallows, which support a narrower range of crops, largely sweet potato. The cultivation of a new garden proceeds in a series of stages, according to which the forthcoming analysis of work is structured (after Conklin, 1961): clear natural vegetation; enclose area with fences and ditches where necessary; pull up roots and pollard trees; burn dead and dry vegetation; till soil and plant crops. Up to the burning-off stage men do the work, women joining them to incinerate small refuse and plant the garden with crops, subsequently tending and harvesting the majority. The stages are fewer when recultivating an established garden: up-root weedy regrowth and any remaining crops; sun-dry pulled-up vegetation and use as compost; till soil, heap into mounds, and plant.

Pigs

Both humans and pigs depend on garden produce, pigs being fed largely sweet potato. The animals are also transacted in socio-political exchanges. The work involved in herding pigs appears considerable at first. It follows the common highlands pattern (Pospisil, 1963; Feacham, 1973; Rappaport, 1968; Hide, 1981; Boyd, 1984). Women are largely responsible for the animals. The daily routine is to release them in the early morning to forage for the day in neighbouring fallow grassland and forest. Troublesome pigs, however, may be kept penned up or tethered on a rope. (This free-ranging arrangement differs from that found in some densely populated highland regions such as Chimbu, where people more often tether or pen animals during the day (Hide, 1981, p. 328), or some Enga who use river flats enclosed by steep banks (Feacham, 1973, p. 27).) Sometimes people put animals in harvested gardens to feed on any remaining tubers and other crops. The Wola say that pigs forage for earthworms mainly, producing layers of fat. In the late afternoon pigs are conditioned to return to the homestead. When they arrive they are fed a tuber ration. They spend the night in stalls, traditionally built at the rear of women's houses, although today many are housed in adjacent lean-to shelters in response to admonitions from mission and government health workers that living with pigs is dirty and unhealthy. Some women regularly manage more pigs than others and are admired for their ability, earning the appellative of *ten howma* as a mark of their widely respected competence; as with men this title carries no authority.

Hunting

The forest supports a varied animal population of marsupials, rodents and birds (Menzies, 1991; Flannery, 1990). In cane regrowth it is relatively meagre, comprising small rodents and birds. The Wola identify by name several hundred animals. These include mammals such as cuscuses, ringtails, bandicoots, echidnas and possums, and birds, some of them distinctive, such as the flightless cassowary and colourful birds of paradise. Other game includes frogs and fish and the occasional large reptile, notably pythons. The most prized are large marsupials, rodents and birds, all pursued by men, with small mammals, frogs and insects being less significant and more often collected by women and children. The Wola employ six of the seven hunting strategies Bulmer (1968, pp. 308–313) identifies for New Guinea: stalking, ambushing, luring, besetting, chasing and trapping animals. Persons can only hunt legitimately on *sem* 'family' territories where they reside or where residents recognize them as rightful kin. They may be accused of poaching if they hunt elsewhere. One of a hunter's most valuable assets is his intimate knowledge of his home territory. He will roam widely across it when hunting, visiting both distant forest and nearby secondary regrowth, the latter supporting fruiting vegetation attractive to game.

Methods

While conceptually straightforward, energy accounting is fraught with methodological problems, particularly in Papua New Guinea for which there are limited data. Although the methods used have advanced considerably since the approach was pioneered, collecting accurate data to match the simple elegance of energy-flow models remains a problem (Pelto, Pelto & Messer, 1989; Ulijaszek 1992, 1995). Its chequered course is due in part to inflated claims relative to available data and research techniques (for example, in the New Guinea highlands, Rappaport's 1968 cybernetic reduction of Maring ritual to an energy management regime: Rappaport, 1977, 1984; Kelly & Rappaport, 1975; McArthur, 1974, 1977; Friedman, 1974, 1979; Bergmann, 1975; Wagner, 1977; Hide, 1981, pp. 549–562). The problems that attend energy accounting have recently prompted a move to using ratios such as the 'physical activity level' (PAL), the ratio of energy expenditure to basal metabolic rate, but data difficulties remain (FAO/WHO/UNU, 1985; James, 1988; James & Schofield, 1990). This paper, depending on secondary sources for physiological data, uses the accounting approach. Some criticize the idea that energy can be used as a common currency to evaluate subsistence activities (Smith, 1979; Foley, 1985, pp. 228–229; Kelly, 1995, pp. 101–108), and we could legitimately use other dietary measures such as protein returns. The energy approach singles out calorific outlays and returns from other nutritional data for comparative purposes because they are human physiological universals readily amenable to quantification (Ulijaszek, 1995). The analysis of energy flows is not intended to suggest that highlanders frame their activities in this way, and certainly not that we can 'assign any absolute values to what one might call a ''coefficient of disinclination'' ', (Healey, 1990a, b, p. 95).

The energy output side of the equation quantifies the work expended in various productive activities. This can be close observation of particular tasks, as in this study's time-and-motion analysis of swidden cultivation, or wider surveys of people's daily activities, which may feature direct observation or random spot checks, as for the pig-herding data, or depend on recall questionnaires or the keeping of diaries, as in the hunting survey reported here (Nydon & Thomas, 1989; Ulijaszek, 1992). The energy expended can be measured in several ways, either in the field or under standardized conditions, using for example indirect calorimetry (measuring rates of oxygen consumption), heart rate monitoring (correlating heart beats with different activities), and doubly-labelled water (using stable isotopes to trace gross daily energy expenditure). The direct measurement of energy expenditure while individuals are actually engaged in various daily tasks, which is the surest method, is intrusive and likely to interfere with normal activity patterns and distort the results: they effectively perform for the researchers. The extent of the sample problem may remain unknown, individuals varying considerably in their energy expenditures, making the extrapolation of results up to the population level problematic, without several time-consuming replicate studies of, for example, swidden cultivation by different households. Such time-consuming direct physiological measurements are expensive and many studies, such as this one, resort to indirect methods and refer to comparable published data on energy expenditure. While every effort is made to use data from populations as near as possible biologically and culturally to the one studied, there is unavoidably a degree of probable error. The data used here come from the Lufa population of the Eastern Highlands, the energy they expended on different tasks being measured by indirect calorimetry using a Max–Planck respirometer (Norgan, Ferro-Luzzi & Durnin, 1974). (Energetics data reported for the Huli, western neighbours of the Wola in the Southern Highlands, are of the same order as the Lufa data. These data are calculated estimates of energy expenditure based on heart rate monitoring, not direct calorimetric measurements, and they are presented as aggregate means for categories of work such as gardening or pig keeping, not according to specific activities, such as clearing or fencing tasks (Yamauchi, Umezaki & Ohtsuka, 2000, n.d.).) The energy expended by the Wola on various subsistence tasks is estimated by the factorial method, multiplying the time people spent on various work by the energy cost per minute.

The energy input side of the equation quantifies the food obtained and consumed from various productive activities. These food inputs are converted to energy and nutritional values either directly by sampling food and undertaking chemical analysis, such as bomb calorimetry, or indirectly, as in this study, by reference to published data on food composition (Ulijaszek & Strickland, 1993). While every effort is again made to use food values reported from the Papua New Guinea highlands region (e.g. Bradbury & Holloway, 1988; Hipsley & Kirk, 1965; Wills *et al.*, 1983; Norgan, Durnin & Ferro-Luzzi, 1979; Hongo & Ohtsuka, 1993), there is an unknown level of probable error regarding the western Wola region. Even where projects can meet the considerable expense of the necessary laboratory work, sizeable margins of error remain, and specimens of the same food from a region can vary widely in composition. Method of preparation can also have a notable impact on energy content, as work on sweet potato shows: tuber energy values in Norgan *et al.* (1979), for example, range from 380 to 669 kJ $(100\ \mathrm{g})^{-1}$ (see also Hongo & Ohtsuka, 1993). If the higher of these values were used in the calculations made here, it would increase by 50% the energy intake. Again, diet surveys are intrusive and may upset people's normal consumption patterns, and the extent of the sample problem may remain unknown, individuals varying considerably in their food intake.

Horticulture

The horticultural data come from close observation of the establishment of a new swidden at a location called Ganonkiyba in the Was valley. The area cleared was 2335 m^2, comprising both forest and cane grass, the two principal vegetation communities (just over one-third of the site (892 m^2) was under *Miscanthus* cane). The forest was of the disturbed variety (although never cleared for a garden in living memory, it was near a settlement and people had collected firewood and raw materials there over many years). The area finally enclosed was 1577 m^2. Five men, related members of the same *sem* community, cleared and enclosed the site, assisted subsequently in burning and planting by female relatives. The men's ages differed, in an attempt to approximate some average male physical working capacity. The area to be cleared was demarcated by cutting a swathe about 2 m wide around its perimeter. Otherwise people worked with no direction or supervision, doing the job as they thought best, resting when they chose. The recultivation data were collected in the same manner, observing the pulling up of vegetation from 117 m^2, the tilling of soil on 164 m^2, and heaping up of sweet potato mounds on 108 m^2. Atypically people worked under constant observation, with the timing of all tasks and other measurements as applicable. A large clock with a second hand was used for the timing, and an attempt was made to note the times of activities to the nearest five seconds. This method was less accurate than using a stop-watch, but that would have necessitated stop–go interference in the work (which was scrupulously avoided), or, impractically, several assistants armed with stop-watches. The probable error in the timings was plus or minus five seconds (see Clarke, 1971, p. 173, for comparative data). The method did not constrain people to single activities. The gardeners frequently hopped from one task to another in a free flow. While this allowed the natural rhythm of work to proceed, it placed a strain on the investigator who, having no control over the proceedings, had to make, and abide by, snap decisions.

All crops harvested from the new swidden were weighed using a spring balance (Table 7); those co-operating in the study brought all crops for weighing before any culinary preparation. These data were supplemented with measurements of households' daily food intake, which involved weighing of food brought back from other gardens (for further data and discussion of food consumed, see Sillitoe, 1983, pp. 217–246). The yields of sweet potato tubers from a sample of long-established gardens were also measured, using the clear harvesting technique (for details see Sillitoe, 1996, p. 44).

Pigs

The pig-herding data come from a survey of people's daily time budgets. The information was collected over 72 days during which thirteen women and twelve men reported daily on their activities over the previous twenty-four hours. The times were estimates. A range of estimating methods were used, including the sun's position in the sky, the start or end of rainfalls or other events known in common to the participants. Also, those involved in the survey were instructed to shout out to the author if they passed his house or if they saw him elsewhere during the day. The investigator could sometimes triangulate between these precisely timed events, and the person subsequently meeting others participating in the survey. On a few occasions the author accompanied the participants during the day and was able to time their activities, these data serving to check the plausibility of the estimated times. During the survey period the thirteen women in the sample herded 26 large pigs for

Table 1. Food values for pork, game and edible wild plants

Food		Source[a]	Edible portion[b]	Energy (kJ $(100\ g)^{-1}$)		Protein (g $(100\ g)^{-1}$)		Fat (g $(100\ g)^{-1}$)		Water (%)	
				C[c]	UC[c]	C	UC	C	UC	C	UC
Pigs											
Pork meat		1		694		30·1		4·1		64·1	
		1		673		19·5		6·5		68·5	
		1		719		27·0		5·4		64·5	
		2		376·6		20·5		0·7		77·0	
		2		384·9		19·6		0·7		76·5	
Pig's liver		2		577·4		22·0		3·8		68·5	
Average value[d]				570·8		23·1		3·5		69·9	
Pork fat		1		2700		4·0		68·3		26·5	
		3		1882		10·0		45·0			
Average value[d]				2291		7·0		56·7		26·5	
Game											
Cuscus	*Phalanger* sp.	1	0·60[e]	844·0	656·0	21·7	16·8	11·3	8·8	64·1	73·0
Flying fox	*Dobsonia*	1	0·85	840·0	606·0	20·5	14·8	9·3	6·7	61·5	73·0
Bandicoot	*Echymipera* sp.	2	0·80	401·7	301·3	21·4	16·1	1·1	0·8	76·0	
Birds[f]	See note	2	0·85	450·5	337·9	19·4	14·6	2·2	1·7	74·6	
Larvae	Cerambycidae	2	1·00	1112·9	834·7	20·2	15·2	19·6	14·7	55·9	
Lizard[g]	*Varanus* sp.	2	0·95	422·6	317·0	23·8	17·9	0·6	0·5	73·0	
Egg	*Gallus* sp.	4	0·85		682·0		12·0		12·4		
Wild plants											
Fungi	*Agaricus* sp.	5	1·0		96·6		1·2		0·3		
Pandan nuts	*Pandanus* spp.	6	0·4		2700		11·9		66·0		
Tree fern fronds	*Alsophila* spp.	7	0·9		180·6		5·5				
Water dropwort	*Oenanthe javanica*	8	1·0		117·6		1·8		0·3		
Palm fruits	*Areca macrocalyx*		Chewed as narcotic								

Footnotes to table on facing page.

1526 days, twelve medium-sized ones for 577 days, six small animals for 343 days and 70 piglets for 1698 days, and three cassowaries for 210 days. These data give a mean pig herd size per day per woman of 1·8 large pigs, 0·7 medium ones, 0·4 small ones, 2·0 piglets and 0·25 cassowaries. Data on pork consumption come from the household food consumption survey mentioned above, and food values from published sources (Table 1).

Hunting

The hunting data come from a diary survey of hunting trips made by a sample of fourteen men and adolescents (see Dwyer, 1974, 1983, on Siane and Etolo work for discussion of methodology). The participants made a total of 329 documented trips. The procedure was that men informed the author as they left to hunt and the time was noted, and they came straight to the author on their return so that it could be noted again. The author accompanied them on a few trips. Sometimes they stayed overnight in a bush house, especially if they had visited a remote locale, and the time they finished hunting and resumed again the next day had to be estimated. This was done again according to the sun's position and other natural time markers, such as when the cicadas started to sing, the early morning cloud lifted from valleys and so on. The total time spent hunting on these diary trips was 2374 h (excluding estimated times it was 1252·95 h). Immediately on the hunter's return, an account of his activities was recorded as a diary entry. If the hunters caught anything, the whole animal was weighed (using a spring balance); these data are used in the calculations of energy returns, again using food values from published sources (Table 1).

Results

Energy expenditure

Horticulture. The data on swidden cultivation suggest that the Wola expend in the region of 4680 MJ ha^{-1} clearing gardens through to harvesting crops (Table 2). The most demanding task overall is harvesting, followed by burning off, which is perhaps apposite given the importance attached to firing in this farming regime. The next most demanding task is clearing roots, followed by transporting planting stock. Next comes the felling of trees and cutting down of understory vegetation, which might intuitively

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Footnotes to Table 1

[a]1, Norgan *et al.* (1979); 2, Ohtsuka *et al.* (1984); 3, Hipsley & Kirk (1965); 4, McCance & Widdowson (1960); 5, Hipsley & Clements (1947); 6, Powell (1976); 7, May (1984); 8, Hongo & Ohtsuka (1993).

[b]After Dwyer (1980).

[c]C = cooked values; UC = uncooked values (calculated after Dwyer, 1983, p. 150).

[d]Values used in this study.

[e]The edible proportion is the same for ringtails (*Pseudocheirus* spp.) and giant rats (*Mallomys rothschildi*).

[f]The average for duck (*Dendrocygna guttata*), brush turkey and pigeon (both indet.).

[g]Used to calculate values for frog.

Table 2. Energy expended in cultivating new swidden (excluding rest periods)

Activity	Male mean energy expenditure[a] (kJ min^{-1})	Female mean energy expenditure[a] (kJ min^{-1})	% male/ % female labour	Time spent on activity at Ganononkiyba (steel tools)	Actual area/distance involved at Ganonkiyba	Energy expended at Gannonkiyba[b] (MJ)	Time spent on activity[h] (ha^{-1})	Energy expended[h] (MJ ha^{-1})
Cutting trees: site clearance & fencing	24·3			25 h 1 min 30 s	722 m^2	72·97	214 h 15 min 19 s	312·38
Cutting cane: site clearance	13·0			6 h 15 min 35 s[c]	446 m^2	9·77	53 h 35 min 37 s	41·80
Splitting wood for posts[d]	18·4			24 h 20 min 20 s	92·8 m	42·27	104 h 54 min 24 s	115·82
Sharpening posts	17·6			16 h 15 min 40 s	105·7 m	23·72	61 h 31 min 58 s	64·98
Clearing ground: fence/ditch line	20·5			23 h 11 min 12 s	166 m	28·52	55 h 52 m 17 s	68·72
Carrying materials: fencing work	29·7			7 h 30 min 20 s	146 m	13·37	20 h 33 min 42 s	36·63
Driving in fence posts	19·2			13 h 56 min 35 s	112 m	20·94	49 h 47 min 47 s	57·37
Tying fence posts	13·8			5 h 24 min 30 s	112 m	5·84	19 h 18 min 56 s	15·99
Digging trench[e]	27·2			6 h 3 min 23 s	9·75 m	19·97		
Cleaning garden: rooting	20·5			59 h 7 min 25 s	786 m^2	153·86	752 h 12 min 32 s	925·20
Cleaning garden: burning off	20·5	13·8	27%/73%	193 h 26 min 58 s	1663 m^2	181·17	1163 h 15 min 21 s	1089·42
Cutting trees: pollarding	24·3			6 h 39 min 35 s	1051 m^2	15·36	63 h 21 min 56 s	92·39
Carrying materials: planting stock[f]		23·0		40 h[g]	1663 m^2	55·20	240 h	331·93
Tilling ground		17·6		25 h 56 min 15 s	1663 m^2	27·39	155 h 58 min 5 s	164·70
Planting sweet potato		17·6		27 h 26 min	1663 m^2	28·97	164 h 57 min 47 s	174·20
Planting other crops	22[g]	17·6	31%/69%	29 h 20 min 25 s	1663 m^2	33·39	176 h 25 min 47 s	200·78
Maintenance, e.g. tying sugar cane	13·4/14·6			3 h 25 min 15 s	1663 m^2	2·87	20 h 34 min 13 s	17·26
Weeding (3 times)	13·4	10·9	33%/77%	27 h 10 min[g]	1663 m^2	20·89	163 h 21 min 34 s	125·62
Harvesting (mainly sweet potato)	14[7]	11·3	10%/90%	354 h[g]	1577 m^2	245·75	2244 h 46 min 7 s	1558·34

Footnotes to table on facing page.

be thought of as the most demanding of gardening tasks. After this come various crop-planting tasks.

The re-cultivation of gardens is not, as one might first assume, more energy efficient overall. At some 4410 MJ ha^{-1} it is similar to clearing and cultivating new swiddens (Table 3). The tasks of tilling the soil, heaping up mounds and planting sweet potato vines are responsible for nearly one-half of this energy outlay, and harvesting again makes a heavy demand. A significant difference is that more of this work falls to women than men, who are responsible for tilling and planting both new and reworked plots. While they expend less energy per unit time than men on any task, women contribute 63% (2954·52 MJ ha^{-1}) of the total energy invested in cultivating a new swidden and 92% (4074·15 MJ ha^{-1}) in recultivating an established garden. The gender-adjusted energy implications are considerable. Women contribute overall 82% of the energy invested in agricultural production, calculated as a ratio of two established gardens reworked for every new swidden cleared. This statistic reflects daily observation, where one more often sees women engaged in farming than men.

Pigs. The data indicate that pig herding is not energetically demanding on average. Herd size is clearly a consideration, and while this can vary considerably, most women herd between two and six animals at any time. The survey data indicate that women spend on average 28 min a day herding pigs or 29 min including cassowaries (Table 4). These mean times apply to a herd averaging about five pigs and 0·25 cassowaries in size. The principal work involves foddering animals, and stalling and releasing them, women spending about 50% of their time on these tasks, which are not onerous. The survey data reveal that men, while acknowledging that female relatives are responsible for pigs, contribute about 20% of the total time invested in pig herding, working an average of 7 min a day. (The Enga spend even less time herding pigs, both women and men devoting only about 6 min daily to it; Waddell (1972), p. 101.) While none of Norgan *et al.*'s 1974 data relate to pig-keeping activities, daily energy expenditure can be calculated from tasks of similar strenuousness, dividing activities into less strenuous (feeding animals, releasing them, tending sick ones, etc.), moderately strenuous (those activities that involve walking, such as leading pigs elsewhere, tethering them out, searching for lost animals, etc.),

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Footnotes to Table 2

[a]According to Norgan *et al.* (1974). These mean energy expenditure values compare with the overall estimates for gardening activities among the Huli of 20·1 kJ min^{-1} for men and 14·2 kJ min^{-1} for women (Yamauchi *et al.*, n.d.).

[b]Calculated as if entire garden established using steel tools (i.e. results adjusted to Ganonkiyba garden totals: area cleared 2335 m^2, area enclosed 1663 m^2 and perimeter enclosed 166 m [as a square]).

[c]Includes some felling of trees.

[d]All fencing data apply to beading fence only.

[e]Includes erection of rampart (making stakes etc.).

[f]Includes estimate of time to collect planting material.

[g]A calculated estimate.

[h]Calculated *pro rata* Ganonkiyba vegetation cover (ha^{-1}) and assuming enclosure entirely bead fence.

Table 3. Energy expended in recultivating garden (excluding rest periods)

Activity	Male mean energy expenditure[a] (kJ min^{-1})	Female mean energy expenditure[a] (kJ min^{-1})	% male/ % female labour	Time spent on activity (steel tools) (ha^{-1})	Energy expended (MJ ha^{-1})
Pulling up herbs & grasses	11·3	10·9	2%/98%[d]	336 h 48 min 30 s	220·43
Carrying materials: planting stock[b]		23·0		240 h[d]	331·20
Tilling soil & planting sweet potato		17·6		1908 h	2014·85
Planting other crops	22[d]	17·6	10%/90%[d]	60 h[d]	64·94
Maintenance, e.g. tying sugar cane	13·4/14·6			40 h[d]	33·60
Fence maintenance[c]	13·8–29·7			51 h 13 min	58·16
Weeding (3 times)	13·4	10·9	33%/77%	163 h 21 min 34 s	125·61
Harvesting, mainly sweet potato	14[d]	11·3	10%/90%	2250 h[d]	1561·95
Total					4410·74

[a]According to Norgan *et al.* (1974).
[b]Includes estimate of time to collect planting material.
[c]Fence maintenance calculated as if beading fence only enclosed entire garden. The calculation assumes that a fence is replaced piecemeal over a decade, taken as equal work at each recultivation for mean computation purposes.
[d]A calculated estimate.

Table 4. Time spent attending to pigs and cassowaries

	Women[b]		Men[c]	
	Time (h)	% waking day[a]	Time (h)	% waking day[a]
Pigs				
Feeding pigs	97·50	0·772	19·00	0·151
Stalling pigs	76·00	0·602	13·00	0·103
Cleaning stalls	2·00	0·016		
Releasing pigs	35·42	0·280	5·58	0·044
Leading elsewhere to release	35·42	0·280		
Tethering pigs out	59·45	0·471		
Checking on pig	32·50	0·257		
Tending sick pig	1·25	0·010	0·50	0·004
Searching for lost pig	47·83	0·379	37·58	0·298
Chasing pigs from gardens	2·00	0·016		
Pig breeding	1·00	0·008		
Singeing piglets' bristles	1·25	0·010		
Transporting pigs across rivers			4·17	0·033
Constructing stalls			18·17	0·144
Totals	391·62	3·101	98·00	0·778
Cassowaries				
Feeding cassowary	18·00	0·143	10·42	0·083
Recapturing escaped bird	0·75	0·006		
Totals	18·75	0·149	10·42	0·083

[a]Taken as 15 h average.
[b]A total of 842 individuals' days (sample of 13 women).
[c]A total of 840 individuals' days (sample of 12 men).

and more strenuous (cleaning stalls, transporting pigs, stall construction, etc.). These values compare with those calculated by Yamauchi *et al.* (n.d.) for the neighbouring Huli of 11·7 kJ min^{-1} expended by men and 13·5 kJ min^{-1} by women in all pig-herding activities combined. According to these calculations, a woman expends 388·4 kJ a day and a man 107·6 kJ attending to pigs (Table 5).

These calculations omit the energy expended in supplying pigs with food, for which women are largely responsible. The Wola feed a substantial 49·8% of their sweet potato harvest to pigs; the average ration fed to a large animal is 2·79 kg daily (Sillitoe, 1983, p. 238). (These findings compare with those elsewhere: the Sinasina feed 48·6% of their sweet potatoes to pigs, the ration ranging from 3·2 kg a day for large animals to 0·8 kg for small ones (Hide, 1981, p. 371).) If the proportion of labour put into cultivating gardens to produce these tubers is included in pig keeping – i.e. about half the energy expended in farming – the energy costs go up dramatically (at 2200 MJ ha^{-1} for new swiddens and 2073 MJ ha^{-1} for established gardens). But it is questionable whether this work should be assigned to pig keeping, as if people undertake it specifically to feed pigs. They feed small, stringy and soft tubers to pigs,

Table 5. Energy expended daily in herding pigs

		Women		Men	
	Energy values (kJ min^{-1})[a]	Time (min)	Energy expenditure (kJ day^{-1})	Time (min)	Energy expenditure (kJ day^{-1})
Less strenuous	12	15·2	182·4	2·7	32·4
Moderately strenuous	16	12·5	200	2·7	43·2
Most strenuous	20	0·3	6	1·6	32
Totals		28	388·4	7	107·6

[a]Values from Norgan *et al.* (1974).

called *showmay hokay* (pig sweet potato), which they consider unfit for human consumption. They do not clear gardens to feed pigs, rather they feed them rejected produce. (This is even more evident with other foodstuffs, which are direct waste from human consumption, such as *Setaria palmifolia* shuckings.) People would undertake more or less the same garden work to feed themselves whether or not they had to fodder pigs, and so the time and energy expended in gardening is not strictly speaking directed towards pig production. Others have noted similar arrangements elsewhere (e.g. Boyd, 1984, p. 35), and tried to estimate the proportion of small tubers people consider unfit to eat. Among the Chimbu, upwards of 25% of tubers are pig food (Brookfield & Brown, 1963, p. 58). Among the Maring, Rappaport (1968, p. 260) maintains that 30–50% of the sweet potato harvest comprises sub-standard tubers. For the Sinasina, Hide (1981, p. 377) has tried to estimate the number of pigs that a garden can support on sub-standard tubers alone and concludes 0·22 ‘pig units’ for every ‘reference’ human-being supported on the produce.

If the labour put into cultivating gardens is discounted, this leaves that put into harvesting and transporting the pigs’ share of tubers. Data on harvesting, from the time survey, suggest that women spend on average 1 h 29 min a day harvesting tubers. The proportion they spend harvesting pig tubers is 42 min (by weight). The average energy expended daily is 474·6 kJ, using Norgan *et al.’s* (1974, p. 343) figure of 11·3 kJ min^{-1} digging tubers. Again it is arguable that women would excavate inferior tubers anyway, as they search for those suitable for human consumption, and so they would use this energy whether or not they had pigs to fodder. Estimating the energy women expend in transporting tubers back to their homesteads is trickier, this involving journeys of less than 1 min to over 1 h (Sillitoe, 1999b). An informed estimation can be made by calculating the distance to the median garden in a sample (calculated both according to number of gardens and their areas; the sample includes 577 gardens with a combined total area of 567,366 m^2). Such a median garden will fall between 5 and 15 min walk from the homestead. If this is taken to represent the mean distance that women travel to their gardens, it can be assumed that the average one-way journey to a garden is 10 min. According to Norgan *et al.* (1974, p. 341), a woman carrying a load expends 23·0 kJ min^{-1} of energy walking uphill and

17·6 kJ min^{-1} walking downhill, and without a load 21·3 and 11·3 kJ min^{-1} respectively. It can be assumed that on a round-trip journey she will spend the same amount of time walking uphill as downhill. On a 20 min return journey a hypothetical average woman, unburdened on her outward journey and heavily laden on her return, will expend a total of 366 kJ of energy.

According to these calculations, and omitting the work put into cultivating gardens, women expend on average 1229 kJ a day in herding pigs, including digging their tuber ration and carrying it back to the homestead. This is an overestimate. If the energy spent digging tubers is halved, on the grounds that the harvest of pig tubers is in part a by-product of digging for human food, and discount the energy expended on the outward journey and reduce by seven-eights that expended on the return (on the grounds again that a woman would expend this energy anyway going to harvest food for human consumption and transporting it back home), a total average daily energy expenditure keeping pigs of 829 kJ is arrived at, which is probably a truer reflection of the cost of pig herding to women. This represents somewhere in the region of 8% of a woman's daily energy expenditure, whereas men only expend about 1% of theirs directly on pig-herding tasks.

Hunting. The calculation of energy expended by hunters is again tricky. Problems are encountered with an activity such as hunting, in which effort varies irregularly, compared with a regular one such as digging a trench, where all that has to be allowed for are differences in work rates and energy consumption between individuals (according to age, physique, etc.). A hunter may go from walking slowly as he stalks through the forest to running full stretch in pursuit of an animal, or from sitting silently in ambush to climbing a large tree. The problems are compounded by men engaging in non-hunting activities during trips, such as collecting firewood, resting, cooking food, and so on. The hunting diary data are too gross to distinguish between time expended on different activities, hunting or non-hunting. So too are the available published physiological data on energy outlays.

According to the Lufa data (Norgan *et al.*, 1974), a man hunting birds uses 15·1 kJ min^{-1} of energy, which falls between that expended walking across level terrain slowly, at 13·0 kJ, and walking normally, at 17·6 kJ min^{-1}. This energy outlay is what the authors anticipate for hunting as 'essentially moderate exercise consisting mostly of rather slow walking through the bush,' (Norgan *et al.*, 1974, p. 342). People expend more energy in hilly terrain, using 25·1 kJ min^{-1} (range 20·9–33·1 kJ min^{-1}) when walking uphill and 13·8 kJ min^{-1} (range 12·6–15·9 kJ min^{-1}) when walking downhill. The Wola spend the greater part of their time hunting across mountainous terrain: they occupy considerably more precipitous country than the Lufa, which possibly adds to their hunting costs. They also engage in some very strenuous activity, such as felling trees to dislodge animals. The energy expended in felling trees is predictably large at 24·3 kJ min^{-1}, while that demanded in activities analogous to setting traps is less, at 17·6 kJ min^{-1} to collect vine and 13·8 kJ min^{-1} to lash fence stakes. After reviewing this evidence, Dwyer (1983, p. 151) concludes that the energy expended on average by the Etolo while hunting in all activities combined falls between 16·65 and 19·42 kJ min^{-1}. This seems a reasonable assumption and this study takes the mean of these two values – 18·04 kJ min^{-1} – to calculate energy

Table 6. Energy expended on hunting trips

Hunter	Time spent (h)	Proportion overnight estimates	Energy expended (kJ)
1	316·73	0·49	342,829
2	291·34	0·77	315,346
3	18·96	0·42	20,522
4	316·03	0·68	342,071
5	288·63	0·55	312,413
6	12·00	1·00	12,989
7	296·99	0·26	321,462
8	19·00	1·00	20,566
9	109·51	0·78	118,534
10	76·35	0·88	82,641
11	11·38	0·00	12,318
12	330·45	0·09	357,679
13	275·41	0·23	298,104
14	11·00	1·00	11,906
Totals	2373·78		2,569,380

expended by Wola hunters. This value is higher than the 13·9 kJ min^{-1} estimate made by Yamauchi *et al.* (n.d.), who only consider less-strenuous gathering activities and not hunting for Huli men. According to these data men expended a total of 2569 MJ hunting for 2374 h during the diary survey, about 1 MJ every hour (Table 6; the table indicates the proportion of trips involving an overnight stay elsewhere, when times were estimated).

Energy returns

Horticulture. The yields from new gardens, according to the Ganonkiyba data (Table 7), total 7360 kg ha^{-1} of mixed crops, comprising 5506 kg ha^{-1} tubers (overwhelmingly sweet potato, at 5410 kg ha^{-1}), 639 kg ha^{-1} green-leafed crops, 77 kg ha^{-1} cucurbit pepos and 1138 kg ha^{-1} other crops (shoots, pulses, etc.). These yields are low and give a false idea of the returns on new swiddens for the labour invested in cultivating them. They are depressed for several reasons. Firstly, the Ganonkiyba soil proved to be *taebowgiy* (poor), that is hard and cloddy, the topsoil thin across the site, with compact clayey subsoil near the surface, in the rooting zone of crops. Secondly, the site suffered from a plague of rats, which attacked some crops, notably those propagated from seed. Thirdly, the garden, located near to homesteads, was ‘discovered’ by some pigs that broke into it several times, rooting it over in places. Fourthly, the garden suffered some erosion damage following a heavy rainstorm soon after it was planted, while the soil was exposed. (The areas denuded of crops by these events are omitted from the yield calculations.) Other data suggest that average yields from newly cleared swiddens may be some three times higher than

Table 7. Yields and energy values of crops harvested from new and established gardens

	Ganonkiyba yields (kg/1577 m^2)	Yields (kg ha^{-1})	% edible	Energy (kJ (100 g)$^{-1}$)	Source	Total energy value (edible portion) (MJ ha^{-1})
Newly cultivated gardens						
Sweet potato	853	5409	95	414	1	21,273·60
Setaria palmifolia	159·9	1014	34	105	2	351·35
Crucifer greens	37·5	238	0	126	3	299·88
Cabbage	29·8	189	0	109	2	206·01
Chinese cabbage	19·7	125	0	96	4	120·00
Beans	14·7	93	60	686	2	382·79
Taro	13·8	88	95	509	5	425·52
Acanth greens	13·7	87	0	126	3	109·62
Cucumber	8·3	53	0	46	3	24·38
Pumpkin	3·6	23	90	184	3	38·09
Maize	2·4	15	30	427	3	19·22
Irish potato	1·5	10	95	314	4	29·83
Ginger	1·0	6	85	272	3	13·87
Sugar cane	0·9	6	30	243	3	4·37
Onions	0·6	4	90	180	6	6·48
Gourd	0·3	2	0	117	7	2·34
Parsley	0·1	1	0	126	3	1·26
Total						23,308·61
Recultivated gardens						
Sweet potato[a]		11,483	95	414	1	45,162·64
Setaria palmifolia		210·7	34	105	3	75·22
Crucifer greens		1·9	0	126	3	2·39
Cabbage		5·0	0	109	4	5·45
Chinese cabbage		0·6	0	96	4	0·58
Taro		5·0	95	509	2	24·18
Pumpkin		321·7	90	184	3	532·74
Maize		20·1	30	427	3	25·75
Irish potato		5·0	95	314	4	14·92
Onions		10·0	90	180	5	16·20
Total						45,860·07

Sources: 1, Bradbury & Holloway (1988); 2, Norgan *et al*. (1979); 3, Hipsley & Kirk (1965); 4, Platt (1962); 5, Wills *et al*. (1983); 6, Peters (1958); 7, Powell (1976).
[a]Some gardens ($n=6$) harvested completely, and others ($n=25$) sampled by the mound and not entire garden.

the Ganonkiyba returns. Data on sweet potato yields from six newly cleared sites give a mean return (with the Ganonkiyba data) of 14,658 kg ha^{-1} (ranging from the Ganonkiyba low of 5409 kg ha^{-1} to 25,900 kg ha^{-1}).

When the energy expended is compared with that obtained from the crops yielded by the Ganonkiyba garden (Tables 2 and 7), there is an expectable poor rate of return at 23,309 MJ ha^{-1}, only five times the energy invested. If the mean yield for new swiddens is taken, with an average sweet potato energy return of 57,649·91 MJ ha^{-1}, and it is assumed that the returns on other crops are depressed by a similar factor, there is an overall energy return of 63,165 MJ ha^{-1}. Furthermore, the Ganonkiyba yields omit the returns from longer term crops such as bananas, sugar cane and pandans, and also some (albeit small) returns on a few others harvested after the yield survey. It can be assumed that the mean energy returns on a newly cultivated swidden are three times or more those calculated for the Ganonkiyba garden. This gives a more healthy rate of return of fifteen times the energy invested in establishing, cultivating and harvesting a new swidden, which is within the range reported for other Melanesian populations, such as the Maring and Enga of the Papua New Guinea highlands (Rappaport, 1972; Waddell, 1972), the Ok-speaking Miyanmin (Morren, 1977), and on Ontong Java in the Solomon Islands (Bayliss-Smith, 1977).

The energy returns from established gardens are of the same order as new ones, the Wola asserting that long-established gardens have sweet potato yields similar to, and sometimes better than, new ones. The mean yield data of 45,860 MJ ha^{-1} from such gardens suggest a fall overall, attributable in part to the reduced variety of crops grown and in part to a decline in staple yield, as some gardens near the end of their productive lives (Table 7). The rate of return on energy is some ten times that invested, according to these data (see Clarke, 1971, pp. 177–179, for comparative data). The nutritional returns from these crops (Sillitoe, 1983, 240–246) are sufficient to maintain a vigorous and expanding population, whatever the apparent nutritional shortcomings of the diet according to certain authorities, notably deficiencies in protein and calcium intakes (Ferro-Luzzi, Norgan & Paci, 1981; Koishi, 1990). They suggest greater ‘affluence’ compared with hunter–gatherer food returns. These calculations assume that the crops grown go to feed the human population, repaying its energy outlays, supplying it with energy to pursue other activities and sustaining its young members, whereas, as has been seen, people feed a considerable proportion of their harvest to pigs. They consume somewhere in the region of 47% of the total energy available in harvested crops. The reductions in energy returns to human beings are considerable, more or less halving the energy input to output ratios. But crops fed to pigs are a further food investment, albeit inefficient in trophic terms.

Pigs. The calculation of energy returns from pork is not straightforward. Unlike the regular daily labour they put into pig keeping, the Wola eat meat irregularly. They may consume little pork for months at a time and then feast briefly on a glut following a large pig-kill festival. On only 7% of days during the household food consumption survey did people eat any pork, at a time when no pig-kills occurred in their vicinity (Sillitoe, 1983, p. 239). These data may be taken to represent everyday pork consumption between infrequent pig-kills. The total weight of cooked meat eaten was 89·7 kg. If it is assumed that men and women ate the same amounts of meat, and for calculation purposes that children ate one-half the adults’ share, average adult pork consumption for this sample was 22·5 g a day. These findings agree with Hide's (1981, p. 507) for the Sinasina: 'households consumed pork, on average, once a fortnight . . . approximately 1 kg of pork per fortnight'. In the Mendi valley families consume pork more often, i.e. five times a month (Lederman, 1986, p. 256). See also Table 1 in Malynicz (1970, p. 203), which gives a range of 0·6–19 g of pork consumed daily per head among the Chimbu.

If it is assumed that the meat comprises one-half fat and one-half lean pork, which is reasonable with the high fat content of Wola pigs, nutritional returns can be calculated using published food values (Table 1). According to these calculations, such a 'daily intake' of pig meat and fat supplies 3·4 g of protein and has an energy value of 322 kJ. These figures may serve for purposes of academic comparison, taken to represent some average level of household pork consumption, but it is necessary to be aware of their hypothetical status. On many days households consumed no pork. Furthermore the amounts of pork eaten during the survey period varied considerably between households, from 29 kg in one homestead to a mere 0·2 kg in another (Sillitoe, 1983, p. 234). The differences increase by another order of magnitude in the few days immediately after a large pig-kill. At this time individuals may eat several kilograms of meat and fat, putting their protein and energy intakes above 150 g and 15,000 kJ a day, with concomitant increased body fat storage and some excretion of excess amino groups (Pellett & Young, 1991; S. J. Ulijaszek, personal communication). This glut pattern of meat consumption has long intrigued ethnographers, among other observers, as a puzzling nutritional practice (e.g. Vayda, Leeds & Smith, 1961).

Another intriguing aspect of the pig-herding regime is that people keep some adult pigs alive for years after they reach maturity. The energetic costs are considerable. If, for the sake of argument, it is assumed that the energy expended in herding pigs by women and men is spread equally between all the animals they herd, a single animal demands 187 kJ a day. (This figure is considerably less than Rappaport's (1968, p. 157) estimate of 525 kJ for the Maring.) While pigs are slow to grow, they reach a reasonable size within 2 years, by which time they will have demanded an energy investment of 137 MJ. If kept until they reach their maximum adult size, which takes 5–6 years, the investment increases to about 400 MJ. And if people keep animals beyond this time, which they often do, sometimes for 10 years or more, they have to expend 68 MJ for every additional year with little, if any, increase in returns. This represents a dramatic increase in trophic energy losses. If it is assumed that an 'average adult beast' weighs 90 kg at slaughter and that 72% of its carcass yields edible products, 50% pork and 50% fat ('killing out' percentages after Devendra & Fuller, 1979, p. 127), it will yield 8·1 kg of protein and 612 MJ of energy. (Both protein and energy adjusted to estimated uncooked values, assuming a 4:3 difference between cooked:uncooked.) After herding a pig for 9 years or so, people enter into an energy deficit relationship with the animal, putting in more energy herding it than they will obtain in return when they slaughter and consume it. Keeping adult animals is folly from the perspective of production and nutrition. But the Wola keep their pigs for other important culturally determined reasons, exchanging them in socio-political transactions. That they can afford such energetically costly practices is a further indication of relative affluence.

Table 8. Food value returns on game caught

Hunter	Animal	Number	Bag weight (g)	Edible portion (g)	Energy (kJ)	Protein (g)	Fat (g)
1	Ringtail	3	2352	1411	9256	237·0	124
	Bandicoot	2	800	640	1928	103·0	5
2	Cuscus	4	5212	3127	20,513	525·0	275·0
	Birds	2	43	37	125	5·0	0·6
3	None						
4	Cuscus	2	2602	1561	10,240	262·0	137·0
	Ringtail	3	4132	2479	16,262	417·0	218·0
5	Cuscus	1	425	255	1673	43·0	22·0
	Dasyure	1	165	132	398	21·0	1·0
	Small rodent	1	50	40	121	6·0	0·3
	Birds	4	123	105	355	15·0	2·0
6	None						
7	Ringtail	4	5441	3265	21,418	549·0	287·0
	Giant rat	1	792	475	1431	77·0	4·0
8	None						
9	Cuscus	2	2377	1426	9355	240·0	129·0
	Ringtail	1	595	357	2342	60·0	31·0
	Bat	1	25	21	127	3·0	1·4
	Frog	1	30	28	89	5·0	0·1
	Larvae	20	67	67	559	10·0	10·0
10	Birds	2	50	43	145	6·0	0·7
11	None						
12	Birds	44	1025	871	2943	127·0	15·0
	Small rodent	2	185	148	446	24·0	1·0
13	Birds	38	2354	2001	6761	292·0	34·0
	Giant rat	1	623	374	1127	60·0	3·0
	Bandicoot	1	396	317	955	51·0	2·5
	Egg	1	7	6	41	0·7	0·7
14	Bird	1	9	8	27	1·0	0·1
Totals			29,880	19,194	108,637	3139·7	1304·4

Hunting. Energy returns on hunting are equally inefficient. According to the diary data, men who made 329 hunting trips of 7·22 h average duration were successful on 23% of them, returning with a total of 122 animals (excluding eggs and larvae). The average returns for a trip were 91 g of meat. Many of the animals were small (birds largely), and on only 8% of trips did hunters return with >200 g of game (Table 8). Expressed in time, men returned with 252 g of meat for about every 20 h hunting. There are relatively few published nutritional values for any New Guinean animals, and none for many in the highlands. This paper uses food values from analyses on a few animals caught elsewhere, and extends those for one species to several others (see Table 1). (Table 1 also gives the proportion of the animals eaten, allowing for bone, fur, feather, claw and other waste (see Dwyer, 1980, 1985a, b).) This information is used to convert the bag weight to that eaten. Furthermore the published food values are for cooked meat and the table converts these to nominal raw meat values as weighed in the survey, allowing for cooking losses (these estimate calculations reduce the values, to compensate for the loss of nutrients in cooking, the reduction in water content and the concentration of nutrients.) The published values are probably for flesh, not composites of all edible parts, when different organs such as heart, lights and liver will vary in nutrient content. Values will also vary between species, and even for the same species with the seasons as, according to the Wola, the fat they carry changes. They may also vary for animals caught in different locales, feeding on different diets. The dubiety of the values notwithstanding, the calculation of nutritional returns is straightforward (Table 8).

A comparison of energy returned for that expended (Tables 6 and 8) reveals a large energy loss: for every unit of energy men expend hunting, they secure in return merely one-twenty-fifth. This ratio does not represent the personal energy returns to hunters, for they do not consume all they catch, but more usually share it with relatives or give it away entirely to others, social interaction and responsibilities featuring prominently in the consumption of game (Dwyer, 1985c). The portion consumed by hunters might make up one-hundredth or less of their energy outlay. The Wola are not alone in their low energy returns, although they have the dubious honour of scoring the lowest benefit-to-cost energy ratio for hunting of any population so far reported in New Guinea. The Siane of the eastern highlands and the Maring of the Jimi Valley evidence similar negative energy balances, albeit they are respectively five and sixteen times more efficient than the Wola (Dwyer, 1974, 1983; Healey, 1990a, b). The difference between these groups may be attributable in part, firstly, to the different energy costs ascribed to their activities (Dwyer, 1983, p. 164, uses an energy cost value one-half of that employed here for the Wola, presumably on the grounds that the nocturnal hunting favoured by the Siane is not very strenuous), and secondly, to the inclusion of different activities in the hunting time budgets (the consideration of 'non-hunting' activities for the Wola, such as non-stalking travel through the forest, taking rests, and so on).

It is possible that wild plant foods could make up the energy deficit incurred in hunting animals. A record was kept of the uncultivated foods collected by men during the hunting trips, and estimates made of those consumed while away in the forest. The principal ones were pandan nuts and fungi, with some tree fern fronds and parsley (Table 1 includes some food values for these forest products). They offset the hunting losses to some extent (Table 9; this omits what was eaten in the forest) but a significant deficit remains. These gathered plant foods add about 710 MJ to the income side of the equation, increasing the energy returns/expenditure ratio to 0·28. This considerable increase in energy returns depends largely on nutritionally rich pandan nuts, which contribute 98% of this added energy. Wild plant foods would be of insignificant nutritional value but for these nuts. These foods help close the yawning energy gap between hunting expenditure and returns, but their nutritional contributions are generally low and unpredictable, with occasional high points when seasonal pandans yield large numbers of nuts.

Table 9. Food value returns on plants gathered

Hunter	Food plant	Number of trips[a]	Weight (g)	Edible portion (g)	Energy (kJ)	Protein (g)	Fat (g)
1	Pandan nuts[b]	5 (7)	12,738	5095	137,565	606	3363·0
	Palm fruits[c]	1 (2)					
2	Pandan nuts	1	2003	801	21,627	95	529·0
	Fungi[d]	1	500*	500	483	6	1·5
3	None						
4	Pandan nuts	1	2101	840	22,680	100	554·0
5	None						
6	None						
7	Pandan nuts	6 (9)	16,834	6734	181,818	801	4444·0
	Tree fern fronds[e]	1	2500*	2250	4064	124	
8	None						
9	Pandan nuts	1 (2)	4110	1644	44,388	196	1085·0
10	Fungi	1	500*	500	483	6	1·5
11	None						
12	Pandan nuts	3 (4)	8214	3286	88,722	391	2169·0
	Fungi	5	2700	2700	2608	32	8·0
	Parsley	1	250*	250	294	5	0·8
13	Pandan nuts	5	8628	3451	93174	411	2278·0
	Fungi	6	4588	4588	4432	55	14·0
14	None						
Totals			65,666	32,639	602,338	2828	14,447·8

*Estimated weights.
[a]Number in parentheses are total number of nuts/fruit bunches collected.
[b]The pandans were not strictly speaking wild (*shorluwk*) but cultivated (*aenk*), that is trees occurring in the forest which men own and which they may tend, sometimes, having planted them.
[c]Sold at market.
[d]Fungi collected were *muwnaen* (*Grifola frondosa*) and *hert* (*Russula* sp.).
[e]*Cyathea* spp., collected to cook with pork at communal mortuary feast.

Conclusions

In the spirit of responding to the sharp student, who after sitting through a lecture on subsistence energy budgets, asked what had been achieved other than to show that people won enough energy to stay alive, it is worth reviewing what such an energy accounting exercise reveals. The evidence confirms the widely held assumption that farming produces more than hunting and gathering for each unit of labour invested, measured in time or energy. The returns-to-expenditure ratio of 4·3 for the !Kung, for example, is only one-third that of the Wola (Lee, 1968). The implication is greater affluence.

The evidence suggests that the costs of this increased affluence are not borne equally by women and men. The highland New Guinea farming system demands proportionately more of women's labour than many hunter–gatherer subsistence regimes (Meehan, 1974; Altman, 1984; Kelly, 1995). The energy budget data quantify starkly the gender differences (see also Yamauchi *et al.*, 2000). Women engage almost daily in horticultural activities in highland society, as any visitor to the region soon observes. If the returns on energy investments in cultivating a new garden are expressed according to a 50%/50% gender division, women see a 7:1 return and men a 32:1 return on their energy outlays. When the re-cultivation of gardens is considered it is seen that women are responsible for some four-fifths of agricultural work measured according to energy outlay. They are also largely responsible for pig management. When labour is compared with pork consumption, women invest some two and one-half times more energy in pig keeping that they receive back, whereas for men the reverse holds and they receive back three times their energy expenditure. On top of these subsistence demands women bear the burden of reproduction, supporting suckling children for long periods. The energetics approach has been employed to monitor the added demands put on women by pregnancy and lactation, and assess reproductive ecology, physiological adaptation, seasonal stress and health status more generally (e.g. Spencer & Heywood, 1983; Panter-Brick, 1989, 1992; Ulijaszek, 1995). The cost of living falls inordinately on women. One's reaction to this will vary depending on ideological viewpoint. Some see it as yet another example, from the Western feminist perspective, of the unfair exploitation of women by men (Josephides, 1985; Modjeska, 1982, 1995), others as an aspect of the Melanesian construction of the person (Lederman, 1986; Strathern, 1988), or as an integral aspect of the society's acephalous constitution which, rather than reflecting exploitation, obviates it (Sillitoe, 1985).

Horticultural production allows people to invest surplus or waste produce in raising valuable domestic animals, which they may manage in ergonomically inefficient ways, although culturally highly esteemed ones. These activities indicate a certain affluence. The energy calculations underline the singularity of pig production in the New Guinea highlands. It is not necessarily energetically negative, people killing many pigs before they incur an energy deficit, harvesting an investment. The data quantify the value put on pigs, their nutritionally rich meat making them apt stores of wealth, converters of poor quality small and stringy tubers unfit for human consumption into high value food. Pig-keeping arrangements alert us to handle the notion of production with care because, from a capitalist economic perspective, Wola behaviour seems illogical. Large pigs are at a premium. They comprise the most valuable wealth that people transact in the socio-political exchanges that occupy a central place in their lives (Sillitoe, 1979b). The energy invested in them contributes to this value. They are not merely stores of protein-rich food but symbols of socio-political success. Pig-kill festivals are the apotheosis of socio-political exchange. The logic driving them is not so much nutritional as transactional. While people are reluctant to dispose of highly valued pigs piecemeal in everyday family consumption, they willingly slaughter large numbers at occasional events attended by hundreds of people. These are truly grand occasions, celebrations of the exchange ethic, at which thousands of pork pieces change hands, men sometimes bedecking themselves festively in their finest feather head-dresses and other decorations. They are the realization of large energy investments within grand social contexts central to the tribal polity. Keeping large mature porkers is attractive under this regime, whatever the energy balance implications. Furthermore men describe organizing and participating in time-consuming exchange events as ‘work’, giving another perspective on gender differences. Work is a relative concept, as is affluence (Kaplan, 2000). Working to produce socio-political order is equivalent to working to produce for subsistence needs. It is a further indication of affluence that society can afford for men to spend so much time engaged in such socio-political activities. It is also a function of population density.

The hunting data further underline the need for circumspection in drawing upon capitalist concepts of production. They indicate that the Wola population could not depend on hunting for subsistence to any extent and exist. If the question asked by Ulijaszek & Poraituk (1993) regarding New Guinea sago production, ‘is it worth the effort’, is posed, the answer is ‘no’. The energy deficit makes it inappropriate to think of hunting as a productive activity. The cost–benefit ratio renders the ideas of optimal foraging theory that were prominent in hunter–gatherer studies a decade or so ago irrelevant (Winterhalder, 1981; Smith, 1983; Dwyer, 1985c). The capitalist-informed notion of optimality suggests that they should stop hunting altogether. An entirely different cultural logic again informs behaviour. It is more akin to a pastime, as Bulmer concluded some time ago: ‘Hunting is a sport, a game, in which man pits himself against animate, if non-human, adversaries,’ (1968, p. 302). Undertaken by men largely, it scarcely qualifies as a subsistence activity, compared with women’s productive endeavours. Again it is arguable that the practice of hunting is a sign of affluence in the wildlife-poor mountain forests of New Guinea, the subsistence regime allowing people to engage in such an energetically costly productive activity. The implications of the energy data discussed are not necessarily that the ancestors of New Guinea highlanders discovered a more efficient subsistence regime in horticulture, evolving from hunter–gatherers to farmers. The hunting and gathering returns are so low as to question the viability of a foraging lifestyle in this region. Whether one subscribes to the affluent hunter–gatherer image or not, it may never have been an option for those inhabiting the mountain forests of New Guinea.

These energy calculations underscore the need to set subsistence arrangements in wider sociocultural context. This is to approach energetics from a non-biological perspective. Studies of human ecology, with their widespread focus on adaptation, have been labelled neofunctionalist. They have been the target of criticisms long levelled at functionalism, of thinking too narrowly about human behaviour, if not appearing to reduce it to satisfying biological needs for food, shelter, reproduction and so on (in the manner, for example, of the renowned ethnographer Malinowski’s 1944 astonishingly deterministic functional theory). It is widely agreed that many aspects of human culture and behaviour have no ready connection with adaptation (Burnham, 1982; Morphy, 1993). Human energy acquisition and expenditure relate to far more than material issues centring on environmental relations, subsistence activities and health status. Energy accounting can usefully throw anomalies into quantitative relief, stressing the need to understand subsistence arrangements, such as swidden agriculture, pig herding and hunting practices, in relation to other logics of production, and to approach with caution associated contestable concepts such as affluence.

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